Tropical deforestation

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Chapter 6

Trade Measures to Combat Tropical Deforestation

6.1 Introduction

In the previous two chapters, several issues related to the individual rainforest exploiters' behaviour have been discussed. The models developed in these chapters reflect the main reasons for unsustainable land use: none of the positive externalities of rainforest conservation were included in the decision-making processes of the individual exploiters, and also uncertainty of property rights was found to result in increased intensity of land use. If governments of tropical forest countries take *all* benefits and costs of rainforest degradation and deforestation into account, they will attempt to correct the market failure resulting from the externalities and to improve the security of property rights as well. In practice, however, many local governments tend to do the opposite and stimulate deforestation both directly and indirectly. They are actively involved in the deforestation process as they allocate concession areas to forestry firms and develop land use plans in which part of the forests is designated to be converted to agricultural use (Dudley *et al.*, 1995, pp. 14-15; Panayotou and Ashton, 1992, p. 26). But they affect deforestation also indirectly, for example by intervening in the prices of natural resources and agricultural output.

Unsustainable land use is stimulated by local governments because forest degradation and even deforestation may be welfare-enhancing from their point of view. The two main reasons are the absence of compensation for the transboundary positive externalities of forest conservation and short-run considerations. As for the existence of externalities, local governments tend to take into account only the *national* benefits and costs of deforestation rather than *all* benefits and costs, unless they receive compensation for the extra conservation efforts (*e.g.*, Ehui and Hertel, 1989). Hence, as long as the positive transboundary externalities are not internalised through compensation in one way or another, the opportunity costs of allocating forested land to alternative use (such as permanent agriculture or cattle ranching) are estimated to be lower for local governments than for the international community: allocation of forest land to alternative forms of land use may be welfare-enhancing from the country's perspective whereas it decreases welfare from a global perspective (Von Amsberg, 1994; see also chapter 2).

Furthermore, short-term considerations can induce local governments to stimulate unsustainable forest use. For example, the perceived necessity to achieve high rates of economic growth in order to improve the welfare of the current generation and to catch up with developed countries can result in excessive exploitation of the country's natural resources. As unsustainable use yields higher benefits in the short run, governments are inclined to stimulate unsustainable exploitation. To illustrate, in many tropical countries prices of natural resources are deliberately kept low in order to stimulate economic activity (Pearce and Warford, 1993, pp. 174-175; Repetto, 1988, pp. 37-39). Also, foreign exchange constraints (possibly exacerbated by high debt burdens) are identified as an impetus to liquidate natural assets: there is some evidence that high debt service ratios stimulate excessive rainforest exploitation (see section 2.5.1, but also Dudley *et al.*, 1995, p. 13; Pearce and Warford, 1993, p. 17; Rietbergen, 1989, p. 64; Schreckenberg and Hadley, 1991, p. 63; Singh and Tabatabai, 1993, pp. 6-7). Furthermore, in some cases forests are used as a safety valve for (social) pressure elsewhere in the country. For example, in some countries colonisation of rainforests is stimulated by the local governments to absorb people who are pushed out of the rural areas outside the rainforest region as a result of increasing land scarcity, caused by either high rates of population growth or by unequal distribution of land (Panayotou and Ashton, 1992, p. 209).

On the basis of this discussion, it can be concluded that both the individual exploiters of the rainforests and the local governments are inclined to use land unsustainably as they underestimate the benefits of sustainable land use, either because they ignore the (transboundary) externalities or due to short-term considerations. Given its interests in forest conservation, the international community contemplates how to create adequate incentives for the actual exploiters and the local governments to improve forest conservation. The two main types of instruments available to the international community are trade measures and foreign aid. The issue of donating aid in order to improve forest conservation is addressed in chapter 7; trade measures are discussed in this chapter.

Since international trade in tropical timber provides a direct link between the international community and the deforestation process, trade measures have received a substantial amount of attention as a potential instrument to combat deforestation. Roughly, a distinction can be made between trade policy measures that aim to reduce the *level* of economic activity in the rainforests and measures that aim to affect the *way* in which rainforest exploitation takes place. The first type are instruments that aim to reduce demand and hence profitability of logging activity; examples are trade bans, import levies, etcetera. Demand-reducing policies lead to depressed (producer) prices at the international tropical timber markets, and therefore it is expected that the level of forestry activities will be reduced.[1] The main aim of the second type of instruments is to make sustainably produced products discernable from unsustainably produced products while aiming to increase the relative profitability of sustainable exploitation. Examples of this type of instruments are preferential taxation of sustainably produced timber and import bans on unsustainably produced timber.

This chapter analyses the effectiveness of trade measures in combatting tropical deforestation. Specific attention is paid to the way in which trade measures affect the decision-making process of both individual logging firms and the local government. In order to assess the potential impact of trade measures, the role of international timber trade in the deforestation process is discussed in section 6.2. Next, the effectiveness of both demand-reducing and discriminative trade measures are analysed in

[1]For example, Barbier *et al.* (1995, p. 417) state that Indonesia's log production fell over the period 1979-1982 as a result of the depressed world prices for timber products.

sections 6.3 and 6.4, respectively. In these sections, the focus is mainly on the local government's land use decisions: the government is assumed to be able to effectively enforce its land use policies. In order to describe the local government's decision process, land allocation models are developed that reflect the two main reasons why deforestation may be welfare-enhancing from the local governments' point of view, whereas it is not for the international community: the existence of (uncompensated) transboundary externalities and short-term considerations (such as foreign exchange constraints).

6.2 Tropical deforestation and the international timber trade

In the literature, there is considerable doubt about whether trade measures are indeed able to substantially affect the rate of tropical deforestation. As has been discussed in chapters 2 and 5, it is a well-established fact that logging activities are not an important direct cause of tropical deforestation: the forestry sector barely inflicts any *permanent* damage upon the forests in terms of biomass; most reports state that the forestry sector is responsible for less than 10 per cent of global tropical deforestation. The alleged ineffectiveness of trade measures in combatting deforestation is exacerbated by the fact that only a very small part of the tropical timber produced is traded internationally. Bourke (1992, cited in Barbier *et al.*, 1994, pp. 8-11) estimates that only about 17 per cent of the logs extracted from non-coniferous forests (which are mainly located in the tropical zone) is used as industrial wood; the other 83 per cent is used as fuelwood for cooking and heating purposes. Of the 17 per cent that is not burnt, about 31 per cent is traded internationally[2], whereas the rest is used locally. On the basis of these percentages, it can be calculated that only about 6 per cent of the tropical timber extracted enters international trade (for comparable figures see Amelung and Diehl, 1992, pp. 22-30; Burgess, 1993, p. 137; Jagels, 1990, p. 33).

Combining the fact that only 6 per cent of the output of the tropical forestry sector is traded internationally and the fact that the forestry sector

[2]Vincent (1994, p. 300) also comes to the conclusion that about a third of the developing countries' industrial roundwood production enters international trade but adds that a large part of the tropical timber exports is traded *between* developing countries.

is responsible for less than 10 per cent of deforestation, it can be concluded that international trade in tropical hardwoods is directly responsible for less than one per cent of tropical deforestation. Thus, trade measures will not have much *direct* impact on the rate of deforestation.

This does not mean that trade measures do not matter at all. First, as has been argued in chapter 5, forestry activities may have important *indirect* effects on the rate of deforestation as they induce subsequent deforestation by opening up the forests. This applies most prominently to the activities of forestry firms that produce timber for the international markets: these firms have heavy equipment at their disposal which is needed to gain access to primary forests, and therefore they are often the first users of this land. Second, environmental damage resulting from logging activities may be substantial. Carefully applied selective logging is estimated to affect less than 15 per cent of the vegetation, but current logging practices often damage up to 50 per cent (Grainger, 1993, p. 84; Myers, 1980, p. 40).

Therefore, if logging firms could be induced to protect their concessions from encroachment and to apply selective logging more carefully, the extent of deforestation and forest degradation due to timber harvesting would be reduced. Thus, trade measures could be useful instruments to achieve those aims.

6.3 The effectiveness of demand-reducing trade measures in improving forest conservation

The main aim of affecting international timber consumption is to reduce pressure on tropical forests through less production for international trade. Several initiatives to reduce the demand of developed countries for tropical timber have been considered and in some cases even implemented. Governments of consumer countries have considered increasing the level of import duties on tropical timber. Furthermore, in some of these countries (like the Netherlands) local councils prohibit the use of tropical hardwood in new houses. Private initiatives have also been developed to reduce tropical hardwood consumption voluntarily: environmentalist organisations have initiated campaigns to persuade Western consumers to abstain from buying tropical hardwoods (Bulte and Van Soest, 1995; ESE, 1992, pp. 75-92).

In this section, the impact of these trade measures on the decision-making processes of the main stakeholders in the tropical countries are analysed. First, attention is paid to the effects on the decisions of logging firms and next on the local governments' land use decisions.

6.3.1 Effects on logging

As a result of reductions in international demand for tropical timber, the producer price of tropical timber will decrease. Obviously, this will result in reduced profitability of logging activities, and therefore (assuming profit maximising behaviour) the extent of logging will decrease. However, it is not likely that the trade flow will decrease much in size. The effectiveness in discouraging timber production will be reduced considerably because the destination of exports would be substituted towards other consumer countries: especially intra-South trade is expected to increase (a trend which is already discernable; see Barbier, 1994, p. 63; Jepma, 1995, p. 23; NEI, 1989; Panayotou and Ashton, 1992, p. 4).

6.3.2 Effects on land allocation

The 'desired response' of demand-reducing policies is that the decrease of timber export prices results in a larger equilibrium size of the forests. The line of argument is that abstaining from forest exploitation becomes relatively cheap as the opportunity costs of non-exploitation are reduced. Assuming that governments aim to maximise welfare consisting of both income earned with forestry activities and the size of the forests, the desired effect of reduced international demand is that local governments are induced to allocate less forest land to logging activities so that forest conservation improves.

However, this argument may be flawed in two respects. In the first place, logging activities may not be decreased as a result of trade measures. This flaw is addressed in the first subsection in which a model developed by Barbier and Rauscher (1994) is presented; this model underlines the fact that excessive forest exploitation is sometimes inevitable in order to meet (short-term) constraints. In the second place, *deforestation* may not be reduced, as is argued in the second subsection on the basis of a model developed by Ehui, Hertel and Preckel (1990). This model emphasises that tropical forest countries generally tend to ignore transboundary externalities while they do take alternative forms of forest use into account. The models presented here are not the original ones but have been slightly modified, the reason being that the modified versions will be used later on (in section 6.4 and in chapter 7).

6.3.2.1 The Barbier and Rauscher model

Barbier and Rauscher (1994) have developed a model to assess the effects of a trade ban on the optimum forest size. The tropical forest country's government is assumed to maximise the present value of future welfare, which consists of the welfare derived from the domestic consumption of timber, from the consumption of imported goods and from the size of the forest stock. The forest stock is an argument in the tropical forest country's welfare function to reflect the domestic benefits of forest conservation (such as watershed protection, genetic diversity and microclimatic functions; Barbier and Rauscher, 1994, p. 77). The country is assumed to face a foreign exchange constraint: in each period the value of the imports should be equal to the value of exports. Tropical timber is assumed to be the country's single export commodity; international timber trade is the only source of foreign exchange. Furthermore, logging is assumed to be the only type of economic activity in the rainforests. Environmental damage is caused as harvesting can take place at an excessive rate (*i.e.*, the harvested quantity exceeds regrowth).

On the basis of their model, Barbier and Rauscher are able to analyse the effectiveness of trade bans in combatting deforestation. Here, a simplified version of their model is presented in this respect that domestic consumption of timber is ignored as it complicates the model without yielding additional insights. Therefore, the tropical forest country is assumed to maximise the present value of welfare derived from consumption of imported goods and from forest conservation, while imports must be paid for by timber sales. Therefore, the country must find the optimal harvesting rate in each period to maximise its objective function:

$$W = \max_q \int_0^\infty U(c(t), F(t)) e^{-rt} \, dt \tag{6.1}$$

$$s.t. \qquad c(t) = Pq(t) \tag{6.2}$$

$$\dot{F}(t) = g(F(t)) - q(t) \tag{6.3}$$

In this model, $q(t)$ is the quantity of timber harvested in period t (measured in biomass), $c(t)$ is the consumption of imported goods, $F(t)$ is the size of the forest (as measured in biomass), r is the country's discount rate, P is the relative price of timber products with respect to imported goods (and hence, in this simple model it is the terms of trade), $\dot{F}(t)$ is the rate of change of the forest biomass over time (*i.e.* the time derivative of the forest stock) and $g(F(t))$ is the regeneration function of forest biomass. The utility function in the objective function (6.1) has the normal characteristics: the first derivatives of this function with respect to either argument (U_c and U_F) are positive whereas the second derivatives with respect to each argument (U_{cc} and U_{FF}) are negative. For the sake of mathematical simplicity, the utility function is assumed to be additively separable, *i.e.* the second-order cross derivatives are zero. Equation (6.2) is the embodiment of the assumption that in each period imports must be paid for with the receipts from timber exports (the foreign exchange constraint). Equation (6.3) is the equation of motion that reflects the rate of change of the forest stock: biomass accumulates through (re)growth but is decreased by timber extraction. The growth function ($g(F)$) is assumed to be a logistic function, which has the properties that its first derivative (g_F) may either be positive or negative but its second derivative (g_{FF}) is strictly negative.

In order to derive the optimal long-run size of the forest area, the model must be solved by taking the appropriate first derivatives of the current-value Hamiltonian:

$$H(q(t),F(t),\lambda(t)) = U(Pq(t),F(t)) + \lambda(t)[g(F(t)) - q(t)] \tag{6.4}$$

In this equation, λ is the costate variable associated with the equation of motion: it reflects the marginal value of the state variable (F) at each moment t.

Applying Pontryagin's maximum principle and assuming an interior solution, the necessary first-order conditions for an optimum solution are (suppressing time notation):

$$PU_c = \lambda \tag{6.5}$$

$$\dot{\lambda} = (r - g_F)\lambda - U_F \tag{6.6}$$

The interpretation of equation (6.5) is that the marginal value of extracting a unit of timber should be equal to its shadow price. Equation (6.6) is an extended version of the Hotelling rule (Hotelling, 1931), stating that the rate of change of the shadow price should equal the opportunity costs of holding on to a unit of forest $(r\text{-}g_F)\lambda$ minus the marginal social value of this unit (U_F).

The steady state is defined as the situation in which all variables have become constant: the time derivatives are set equal to zero (Kamien and Schwartz, 1981, p. 88).[3] Hence, the steady state is determined by:

$$(r - g_F^*)PU_c^* = U_F^* \tag{6.7}$$

$$q^* = g(F^*) \tag{6.8}$$

Note that, given the assumption that U_c and U_F are both nonnegative (the non-satiation assumption), $(r\text{-}g_F)$ must be positive for a steady state to exist. Basically, g_F indicates how the rate of forest growth changes with respect to the forest biomass: it can therefore be interpreted as the direct return on retaining the marginal unit of forest biomass. Thus, the condition that g_F is allowed to be smaller than the discount rate r can be interpreted as follows: given the fact that the decision maker derives utility from the existence of forests ($U_F > 0$), he is willing to accept an 'own rate of return on the forest' that is less than the discount rate r. Indeed, if the forest stock were not an argument in the utility function, the rate of return on forest assets should be equal to the discount rate (see for example Hanley *et al.*, 1997, pp. 181-182).

[3]Just like the model presented in section 4.3, this is a renewable resource problem with an infinite terminal time. This problem's transversality condition is therefore similar to the one discussed in section 4.3.2. Setting the time derivatives of the state and control variables (and hence the time derivative of the current-value shadow price) equal to zero yields an optimum that satisfies the transversality condition.

Now the effects of indiscriminate trade measures can be analysed. A trade ban, voluntary consumer action and an import tax on tropical timber in consumer countries will reduce the terms of trade (Barbier and Rauscher, 1994, p. 81). Therefore, in order to analyse the effectiveness of indiscriminate trade measures, the impact of a change in the terms of trade (P) on the equilibrium forest size (F^*) must be analysed. The comparative statics are the following[4]:

$$\frac{dF^*}{dP} = \frac{(r - g_F^*)U_c^*(1 + \eta_c^*)}{D} \tag{6.9}$$

In this equation, η_c denotes the elasticity of marginal utility of the consumption of imported goods with respect to quantity of imports consumed (that is, $\eta_c = (c\,U_{cc})/U_c < 0$) and D is the determinant of the equilibrium system consisting of equations (6.7) and (6.8). As is shown in appendix 6.1, the determinant is unambiguously negative. Hence, given the fact that r-g_F is always nonnegative, the sign of the first derivative depends crucially on the value of the elasticity of marginal utility of the imports consumption (η_c).

The interpretation of this result is as follows. As can be inferred from equation (6.7), keeping all other variables fixed, a reduction in the terms of trade implies that U_F^* can also be reduced (that is, the equilibrium forest size can be increased): a declining terms of trade makes forest conservation cheaper compared to consumption of imported goods. However, keeping all other variables fixed is not appropriate: reduced consumption of imported goods implies that the marginal utility of consumption (U_c^*) will increase. If the absolute value of η_c is less than one (that is, a decrease in consumption of imported goods results in a less than proportional increase in marginal utility), the desired result is achieved: a deterioration of the terms of trade results in a higher equilibrium forest stock. But if the absolute value of the elasticity is larger than one[5], the LHS of equation (6.7) actually increases so that the marginal utility of forest conservation must also increase. This implies that the forest stock must be reduced: a

[4]The necessary steps to be taken to derive this result are presented in appendix 6.1.

[5]This situation is labelled by Barbier and Rauscher (1994) as ’import dependency’.

deterioration of the terms of trade implies that more timber has to be exported to earn a sufficient amount of foreign exchange in order to limit the fall in consumption of imported goods. Therefore, the long-run equilibrium forest size may or may not increase as a result of demand-reducing policies in the importing countries.

6.3.2.2 The Ehui, Hertel and Preckel model

One of the most important assumptions of the Barbier and Rauscher model is that timber exploitation is the only type of economic activity in rainforests. However, forests can also be converted to alternative forms of land use, such as agriculture. If an alternative form of land use is introduced, the case for trade bans becomes even weaker as is forcefully demonstrated by Ehui, Hertel and Preckel (1990). They developed a model which takes alternative uses of forest land into account, and which has been empirically applied to the Ivory Coast by Ehui and Hertel (1989). In the Ehui, Hertel and Preckel model (subsequently referred to as the EHP model), by choosing the optimal rate of deforestation in each period the social planner maximises the net present value of the aggregate benefits of forest use, consisting of the benefits rendered by forested land (in the form of timber revenues and benefits yielded by other forest functions) and the benefits of agricultural conversion. In the empirical application by Ehui and Hertel (1989), only the domestic *economic* benefits of deforestation and forest conservation are taken into account; in this model forests contribute to national income by producing timber and via their positive effect on agricultural productivity.

In order to analyse the effects of a trade ban on land allocation, a simplified version of the EHP model is used here. The tropical forest country aims to maximise the net present value of forest exploitation by choosing the optimal rate of deforestation in each period. Net revenues arise from logging the entire forest area selectively (which does not lead to deforestation) and from agriculture (which causes deforestation as forest land has to be cleared). Thus, not all environmental functions are taken into account; only the domestic economic benefits are included in the decision-making process of the local government. Other modifications are that the use of agricultural inputs is ignored, that the timber demand function is assumed to be downward sloping[6], and that all equations are specified. Thus, the land use decision process of the local government is modelled as follows:

$$\Pi = \max_D \int_0^\infty \pi(t) e^{-rt}\, dt \tag{6.10}$$

$$s.t. \quad \dot{F}(t) = -D(t) \tag{6.11}$$

$$\pi(t) = P_M(t) q_M(t) + P_A(t) Z(t) [F_0 - F(t)] \tag{6.12}$$

$$q_M(t) = \gamma_M F(t) + (1 - \gamma_M) D(t) \tag{6.13}$$

$$P_M(t) = \bar{P}_M - \theta_M q_M(t) \tag{6.14}$$

$$Z(t) = \bar{Z} + \alpha D(t) - \beta [F_0 - F(t)] \tag{6.15}$$

Equation (6.10) reflects the assumption that the government maximises total discounted profits of forest exploitation Π by choosing the optimal rate of deforestation (*D*, measured in units of land) in each period; profits in each period ($\pi(t)$) are discounted at rate *r*. Depletion of the forest stock is represented by equation (6.11), the equation of motion: the size of the forest stock (*F*, measured in units of land) falls over time at the rate of deforestation *D*. As can be inferred from equation (6.12), profits[7] are made in each period because of two activities: forestry and agriculture. Profits earned from forestry activities equal $P_M q_M$. Here, P_M is the net value of the quantity of commercially valuable timber per unit of land. Thus, the unit

[6]Barbier *et al.* (1994, p. 43) present evidence that the own price elasticity of demand for tropical timber is quite low, so that the demand function can be assumed to be downward sloping.

[7]As production costs are ignored, profit maximisation coincides with revenue maximisation.

of measurement is the entire stock of commercially valuable timber present on a unit of land, and hence q_M is the quantity of timber extracted in terms of this unit of measurement. Equation (6.13) shows that timber is extracted by selective logging and by clearfelling. In line with actual practice, selective logging is assumed to be more profitable than clear-felling (if only the timber revenues are compared). Indeed, selective logging is the technique most often applied in rainforests; Amelung and Diehl (1992, p. 19) state that clearfelling is only commercially profitable if land is to be converted to alternative uses. Thus, the entire forest area is assumed to be logged selectively; γ_M is a constant that reflects the average fraction of trees that is harvested per unit of land in each period under a selective logging regime.[8] However, forestry activities take place excess-ively on land that is to be converted into agricultural land in the same period (which is denoted by $D(t)$). The quantity of commercially valuable timber still present on such a unit of land is the fraction that has not yet been removed under a selective logging regime $(1-\gamma_M)$.[9] As is shown by equation (6.14), the timber demand function is assumed to be downward sloping.

Returning to equation (6.12), the second source of income is agricultural production: agricultural revenues can be calculated by multiplying the monetary yield per unit of land (the price of agricultural products P_A times the average per-unit land productivity Z) by the area of land allocated to agriculture (F_0-$F(t)$). As is shown in equation (6.15), land productivity is not fixed. On the one hand, current deforestation (D) contributes to average soil productivity as burning of the forest cover increases average soil productivity because of the release of nutrients (Hecht, 1985; see also section 4.2). A newly deforested area is very fertile in the short run, but it can be cultivated for only a limited period of time

[8]This does not imply that an area is logged every year: the *average* quantity of trees which is harvested per year can be calculated as the total quantity of timber removed in a rotation cycle divided by the length of the rotation period.

[9]Alternatively, equation (6.13) can be written as $q_M=\gamma_M(F-D)+D$. Taking the entire stock of commercially valuable timber on a unit of land as the unit of measurement, the total quantity of timber harvested is the quantity of timber extracted from the area of land that is to be converted to agricultural use (D) and the selectively harvested timber in the rest of the forest (F-D).

as soil productivity falls quickly during cultivation because of nutrients depletion (Herrera *et al.*, 1981; López and Niklitschek, 1991; OTA, 1984); therefore only *current* deforestation contributes to average soil productivity. On the other hand, the proximity of forest cover increases average soil productivity because it prevents erosion and accelerates soil formation by shedding organic material onto the fallow land (Ehui *et al.*, 1990). Hence, *cumulative* deforestation (F_0-F) has a negative effect on average soil productivity.[10] Finally, the agricultural sector is assumed to be confronted with a fixed price for the agricultural yield per unit of land ($\bar{P}_A$).[11]

In order to derive the optimal long-run (equilibrium) size of the forest area, the model must be solved by taking the appropriate first derivatives of the current-value Hamiltonian of this model:

$$H(D(t),F(t),\lambda(t)) = \left[P_M(t)[\gamma_M F(t) + (1-\gamma_M)D(t)] + \bar{P}_A Z(t)[F_0 - F(t)]\right] - \lambda(t)D(t) \qquad (6.16)$$

In this equation, λ is again the costate variable. Assuming an interior solution, maximisation of the Hamiltonian yields the following first-order conditions:

$$\lambda(t) = (1-\gamma_M)P_M(t) - \theta_M(1-\gamma_M)q_M(t) + \alpha\bar{P}_A(F_0 - F(t)) \qquad (6.17)$$

$$\dot{\lambda}(t) = r\lambda(t) - \gamma_M P_M(t) + \theta_M\gamma_M q_M(t) + \bar{P}_A Z(t) - \beta\bar{P}_A(F_0 - F(t)) \qquad (6.18)$$

On the basis of the equation of motion (6.11) and the first-order conditions (6.17) and (6.18), together with the inverse demand function for timber (6.14) and the timber supply function (6.13), the model can be solved. The equilibrium size of the rainforest area can be found by setting the time

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[10]Obviously, it is a crude simplification to use *average* agricultural productivity, especially when *marginal* deforestation decisions will be analysed subsequently. However, this approach is mathematically simple, while the final conclusions will not be altered qualitatively if soil productivity is modelled in a more sophisticated way. For the importance of using *marginal* productivity in determining the long-run forest size, see Bulte *et al.* (1997).

[11]This assumption does not affect the conclusions of this model but facilitates the mathematics.

derivatives ($\dot{F}$ and $\dot{\lambda}$) equal to zero.[12] The resulting equilibrium forest size (F_M^*) is presented in equation (6.19):

$$F_M^* = F_0 - \left(\frac{\bar{P}_A \bar{Z} - [\gamma_M - r(1-\gamma_M)][P_M(0) - \theta_M \gamma_M F_0]}{(2\beta - r\alpha)\bar{P}_A + 2\theta_M \gamma_M [\gamma_M - r(1-\gamma_M)]} \right) \qquad (6.19)$$

Although this equation may appear to be messy at first sight, the interpretation is straightforward. The numerator of the second term on the RHS basically reflects the net present value of converting the *first* unit of forest land: the present value of the economic benefits of deforesting the first unit of land are weighed against the present value of the economic benefits of selective logging, as can be seen by rewriting the numerator as follows:

$$(1-\gamma_M)\left[P_M(0) - \theta_M \gamma_M F_0\right] + \frac{\bar{P}_A \bar{Z}}{r} \overset{?}{\geq} \frac{\gamma_M}{r}\left[P_M(0) - \theta_M \gamma_M F_0\right] \qquad (6.20)$$

The discounted benefits of selective logging are $\gamma_M P_M(0)/r$ while the discounted benefits of deforesting are the one-shot timber revenues resulting from conversion logging $(1-\gamma_M)P_M(0)$ plus the present value of the agricultural revenues $\bar{P}_A \bar{Z}/r$. Furthermore, as the timber demand function is assumed to be downward sloping, the effects of the decision whether or not to deforest on the sales price should be taken into consideration. On the one hand, deforesting the first unit of forest land implies that in the future there will be less supply of selectively logged timber, resulting in a price increase: the discounted benefits of deforesting the first unit of land arising from the price increase are $\gamma_M^2 \theta_M F_0/r$. On the other hand, the additional timber extracted from a unit of land that is to be converted to agriculture results in a decrease in the price at which total timber supply can currently be sold: the price falls with $(1-\gamma_M)\gamma_M \theta_M F_0$. Thus, the numerator determines whether at least some deforestation is desirable, or not.

[12]Given the fact that the time horizon is infinite while there are no constraints on the size of the stock (except that it is nonnegative), the transversality condition associated with this dynamic optimisation problem is similar to the one presented in section 4.3.2. Again, the equilibrium size of the forest thus found satisfies the transversality condition.

The denominator basically acts as a multiplier. In the EHP model, it is crucial that 2β exceeds $r\alpha$; otherwise, equation (6.19) does not provide an optimum for the planning problem. Hence, if the increase in agricultural yield from *current* deforestation (α) is very large compared to the present value of the contribution of the forest stock to agricultural yield (β) given the discount rate (r), the model collapses. In their empirical application of this model, Ehui and Hertel (1989) find that in the case of Ivory Coast the denominator is positive. In the model used in this section, the fact that the demand function for timber is downward sloping (θ_M is positive) implies that it is even more likely that the denominator is positive.[13]

The EHP model demonstrates that demand-reducing policies may not have a beneficial effect on forest conservation. If international demand is reduced, the demand function for timber shifts to the left, and hence the vertical intercept of the function is reduced. Thus, in order to determine the consequences of implementing demand-reducing policies, the first derivative of F_M^* with respect to $\bar{P}_M$ should be calculated. As is clear from equation (6.19), this derivative has a positive sign, which means that a decrease in the price of timber results in a smaller long-run forest size. The interpretation is that a leftward shift of the demand function for timber decreases the value of the forest as a producer of timber, so that alternative uses of forested land (agriculture in this model) become relatively more profitable. In other words, demand-reducing policy measures may well reduce the local benefits of forests (that is, by reducing timber revenues) and lead to a lower equilibrium size of forest land as viewed by governments of tropical countries. The same argument has been put forward by various authors, such as Barbier *et al.* (1994), Burgess (1993), ESE (1992, p. 37) and Vincent (1990b).

[13]The assumption that initially the entire forest area is logged selectively rather than that clearfelling takes place, implies that the discounted profits of selective logging ($\gamma_M P_M(0)/r$) exceed the one-shot profits of clearing the residual stand ($(1-\gamma_M)P_M(0)$). Consequently, the term $(\gamma_M - r(1-\gamma_M))$ is positive.

6.3.3 Conclusions on the effectiveness of demand-reducing policies

In this section, the two main arguments concerning the (in)effectiveness of demand-reducing policies have been presented. The general idea behind implementation of demand-reducing policies is that they decrease the profitability of forestry activities in rainforest areas, so that the level of logging activity will be reduced. In terms of the incentives to individual firms, this line of argument is probably valid; if (profit maximising) forestry firms were the only actors to decide, less forest activity would take place. However, governments are also stakeholders in the process. The general result of reducing international demand for tropical timber is that allocating land to forestry activities becomes less profitable, so that either more forest biomass is conserved (Barbier and Rauscher) or more land is allocated to alternative forms of land use (EHP). Therefore, forest conservation may go either way. Furthermore, Barbier and Rauscher draw attention to the fact that if governments are faced with an import constraint, a reduction in international timber prices may stimulate logging activities rather than discourage them if the country is import-dependent.

Obviously, this discussion is rather crude in the sense that it is not appropriate to state that trade bans, voluntary consumer action and an import tax on tropical timber will have the same result. The reason is that rents will occur as a result of these policy measures, but that the recipient of these rents differs. In the case of a reduction of timber demand resulting from an import ban or voluntary consumer action, demand for timber substitutes (such as plastics, aluminium or temperate timber) will be stimulated. In the case of an import tax, governments of consumer countries capture the rents. Depending on the way in which this extra government income is spent, additional incentives can be given to the local governments to improve forest conservation: pressure on the forests can thus be relieved (see for example Jepma, 1995, p. 44).

6.4 The effectiveness of selective trade measures in improving forest conservation[14]

Apart from trade measures that aim to reduce the *level* of economic activity in the rainforests, measures have been developed that aim to affect the *way* in which rainforest exploitation takes place. Currently, only a very small percentage of the wood extracted from rainforests is produced sustainably: from a total of 828 million hectares of the tropical forests under production in 1985, less than 1 million hectares were logged under a sustainable management regime (Poore *et al.*, 1989, p. 196; see also Rice *et al.*, 1997). Indeed, in the present situation there is not much incentive to apply sustainable techniques, mainly because sustainably produced timber cannot be distinguished from unsustainably produced timber. If such a distinction can be made, an appropriate incentive structure may arise which effectively results in improved forest conservation. Several types of instruments have been developed. Trade bans on unsustainably produced timber may be implemented so that only sustainably produced timber enters South-North trade. Furthermore, selective import duties can be envisaged: sustainably produced timber may be imported duty-free while a levy is placed on unsustainably produced timber. Finally, consumer preferences may already be sufficient to give appropriate incentives: if consumers in developed countries prefer sustainably produced tropical hardwoods to unsustainably produced hardwoods, a price premium arises on sustainably produced timber (ESE, 1992).

Obviously, at the intergovernmental level, trade measures aimed at improving the environmental situation in exporting countries are politically very sensitive. Still, several attempts have been made to develop such instruments. For example, in the early 1990s the Dutch government decided that after 1995 all unsustainably produced tropical timber would be banned. As this was a unilateral decision, the Netherlands were confronted with harsh criticism from exporting countries (Bulte and Van Soest, 1995; Kolk, 1996, p. 161). The ban has not been implemented because of two reasons. First, it may not be possible legally to install a unilateral trade ban on environmentally unsound products: the precedent

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[14]This section is based on Van Soest, D.P. and C.J. Jepma (1997), "Certification and Tropical Deforestation: Micro Monitoring without Macro Conditions?", *Mitigation and Adaptation Strategies for Global Change*, **2**(4), in press.

of the 'non dolphin-safe tuna' conflict between the US and Mexico suggests that such a ban may not be implementable within the GATT framework (ESE, 1992, pp. 49-50). Second, it may even contravene EU regulations (Barbier *et al.*, 1994, pp. 119-120). An example of multi-lateral trade negotiations at the governmental level is the ITTO Year 2000 target. Members of the International Tropical Timber Organization (a forum of tropical timber producing and tropical timber consuming countries) have signed an agreement that from the year 2000 onwards, an import ban will be established on all unsustainably produced tropical hardwoods (Barbier *et al.*, 1992a, p. iii; ITTO, 1992).

With respect to private initiatives, several examples can be given. First, environmental NGOs have cooperated in constructing a certification scheme, the Forest Stewardship Council's certification scheme (see Dudley *et al.*, 1995, pp. 145-150; ESE, 1992, p. 102). Furthermore, industry self-regulation has emerged in the sense that some companies have made a commitment to secure timber only from sources where sound forest management is applied (ESE, 1992, pp. 75-92).

In this section, the effects of introducing discriminative trade measures on the decision-making process of both the forestry sector and the local government are analysed. The focus is on the long-run size of the forest area and on the speed at which deforestation occurs, because the introduction of a certification regime will not only have consequences for *cumulative* deforestation but also for the *rate* of deforestation. The reason is that segmenting the timber market may give incentives for the local governments to increase the rate at which rainforest land is converted to agricultural use. The importance of not only analysing the long-run situation but also the depletion path towards it, stems from the fact that the actual loss of a tropical forest ecosystem is to a large extent irreversible (Kolk, 1996, p. 129). If forests are cleared and converted to (permanent) agricultural use, the ecosystem is destroyed. Although regeneration of the forests in terms of *biomass* may still be possible, it is likely to be very costly and the damage in terms of *biodiversity* will largely be irreversible (that is, it will take a very long time before biodiversity is fully restored; see also Albers *et al.*, 1996). Hence, the longer conversion of a parcel of forest land is postponed, the better: if in the (near) future developments take place that reduce the necessity of deforestation, the larger the forest size, the better (see also Dudley *et al.*, 1995, p. 3).

The consequences of introducing a certification regime for individual firms and the effects on the local government's land use decisions are discussed in the following two subsections.

6.4.1 The decision-making process of individual logging firms

The main characteristic of the selective trade measures mentioned above is that the producer price for sustainably produced timber increases relative to the producer price of unsustainably produced timber. However, this does not necessarily imply that forestry firms will switch to sustainable production techniques as these are generally more costly.[15] Basically, individual firms that are confronted with a certification regime compare the net present value of sustainable logging (referred to with subscript S) to the net present value of unsustainable logging (denoted with subscript U). The firm faces the following maximisation problem:

$$\max \left[NPV(P_S, C_S, I_S),\ NPV(P_U, C_U, I_U) \right] \tag{6.21}$$

The firm's choice depends on variables such as the difference between the per-unit price at which certified timber can be sold (P_S) and the price of unlabelled timber (P_U), and also on the difference between the per-unit costs involved in sustainable logging (C_S) and unsustainable harvesting C_U). Furthermore, the decision has investment characteristics: for example, meeting certain criteria (such as minimum stem size requirements) implies that some harvesting must be postponed while there are also genuine investment expenditures to be made that are smaller (or even absent) if logging is undertaken unsustainably (I_S exceeds I_U). This implies that the firm's time horizon plays a role as well: variables like the firm's discount rate, the duration of the concession contract and expectations about the likelihood of renewal are also important to the outcome.

Thus, if the costs of meeting the sustainability requirements are more than compensated by the difference between revenues of certified and

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[15] According to Ferguson and Munoz-Reyes Navarro (1992), meeting the sustainability criteria as formulated by ITTO increases production costs by US$ 0.3-1.5 bn. See also Myers (1980, p. 40) and Varangis *et al.* (1995).

nonlabelled tropical timber (given the time horizon of the logging firm), individual firms will have a distinct incentive to apply sustainable production techniques.

6.4.2 The decision-making process of the local government

As can be easily conceived, the introduction of a certification regime may not be able to stop deforestation: even if sustainable logging is optimal for individual loggers, conversion to alternative forms of land use may still take place. Indeed, the local government does not only compare the benefits of sustainable logging and unsustainable logging: the contribution of agriculture to GDP is also taken into account. Hence, in drawing up its land use plans, the government of a tropical forest country compares the benefits of (sustainable) forestry activities with the benefits of agricultural conversion.

By making a distinction between sustainably and unsustainably produced timber, the international community is able to affect the local government's land use decisions. In order to analyse the effects of introducing a certification scheme in terms of short- and long-run forest conservation, a model is built that can be compared with the situation without a certification regime. Given the fact that certification aims to internalise the transboundary external effects of sustainable land use into the decision-making process of the various actors, the Ehui, Hertel and Preckel (EHP) model as presented in section 6.3.2.2 is used as a benchmark. First, in section 6.4.2.1, the EHP model is adapted to include segmented timber markets. Subsequently, in section 6.4.2.2 the resulting long-run equilibrium size of the forest is derived which can be contrasted with the long-run equilibrium size of the forest in the absence of a certification regime, as given by equation (6.19). In section 6.4.2.3 the depletion paths are presented for both segmented and unsegmented markets. Application of comparative statics to these long-run equilibria and corresponding depletion paths shows that a market situation can arise in which the *long-run* forest size increases after the introduction of a certification regime but in which the instantaneous *rates* of deforestation increase as well. The conditions under which this trade-off occurs are presented in section 6.4.2.4 together with evidence on its likelihood in reality. Finally, conclusions are drawn in section 6.4.2.5.

6.4.2.1 The model

In order to illustrate the argument, the EHP model is extended by distinguishing between sustainable and unsustainable logging. Regarding the desirability of sustainable logging for individual firms, it is assumed that the resulting market situation after the introduction of a certification regime is such that sustainable logging becomes more profitable than unsustainable logging. Thus, each individual logging firm would like to switch to sustainable forestry techniques; the certification scheme is assumed to be very effective. However, when the local government decides that a forestry firm's concession area is to be converted into agricultural land, the concession is not renewed and therefore the forestry firm will decide to extract all commercially valuable timber still present in the concession area; in other words, it will then switch to unsustainable exploitation.

Assuming that the local government can effectively determine land use, its decision process is modelled as follows:

$$\Pi = \max_D \int_0^\infty \pi(t)e^{-rt}\,dt \tag{6.22}$$

$$s.t. \quad \dot{F}(t) = -D(t) \tag{6.23}$$

$$\pi(t) = P_S[\gamma_S F(t)] + P_U[(1-\gamma_S)D(t)] + P_A(t)Z(t)[F_0 - F(t)] \tag{6.24}$$

$$P_S(F) = \bar{P}_S - \theta_S\,(\gamma_S F) \tag{6.25}$$

$$P_U(D) = \bar{P}_U - \theta_U(1-\gamma_S)D \tag{6.26}$$

$$Z(t) = \bar{Z} + \alpha D(t) - \beta[F_0 - F(t)] \tag{6.27}$$

Comparing this model with the modified EHP model presented in section 6.3.2.2, the main distinction is that the market for timber is now segmented into a market for sustainably produced timber and a market for conversion timber. The main changes are embodied in equations (6.24) to

(6.26). The profit function (6.24) reflects the assumption that sustainable logging is assumed to be more profitable as the first term on the RHS shows that profits are earned by sustainably logging the *entire* forest area ($F(t)$). If it is assumed that γ_S is the fraction of commercially valuable biomass that can be harvested sustainably per unit of land in each period ($\gamma_S < 1$)[16], the net revenue of sustainable logging per unit of land is $\gamma_S P_S$, where P_S denotes the price per unit of land at which this type of timber can be sold at the international markets. Unsustainable logging takes place on hectares that are to be converted into agricultural land. Because the quantity of commercially valuable timber still present on such a unit of land is the fraction that has not yet been removed under the sustainable logging regime (*i.e.*, $1\text{-}\gamma_S$), the net revenues earned by excessive logging per unit of land are $(1\text{-}\gamma_S)P_U$. The two separate demand functions with which the tropical country's forestry sector will therefore be confronted, are shown in equations (6.25) and (6.26). Again, the inverse demand functions are assumed to be linear and downward sloping, and $\bar{P}_i$ denotes the maximum price while θ_i is the coefficient that reflects the amount with which the price falls if quantity supplied is increased by one unit (for $i = S,U$).

In order to derive the optimal long-run (equilibrium) size of the forest area and the path towards this equilibrium, the model must be solved by taking the appropriate first derivatives of the current-value Hamiltonian of this model (suppressing time notation):

$$H(D,F,\lambda) = \Big[P_S[\gamma_S F] + P_U[(1-\gamma_S)D] + \bar{P}_A Z[F_0 - F]\Big] - \lambda D \qquad (6.28)$$

Maximising this Hamiltonian yields the following first-order conditions (assuming that an interior solution exists):

$$\lambda(t) = (1-\gamma_S)P_U(t) + \alpha\bar{P}_A[F_0 - F(t)] - \theta_U(1-\gamma_S)^2 D(t) \qquad (6.29)$$

[16] As was also the case in section 6.3.2.2, this does not imply that an area is logged every year: the *average* quantity of trees harvested per year can be calculated as the total quantity of timber removed in a rotation cycle divided by the length of the rotation.

$$\dot{\lambda}(t) = r\lambda(t) - \gamma_S P_S(t) - \beta\bar{P}_A[F_0 - F(t)] + \bar{P}_A Z(t) + \theta_S\gamma_S^2 F(t) \qquad (6.30)$$

The interpretation of (6.29) is as follows. The RHS reflects the benefits of deforesting a unit of forested land, which are equal to the sum of the direct revenues of deforestation in terms of timber sold and the increased agricultural productivity arising from deforesting this extra unit of land minus the loss in revenues resulting from the decrease in price of non-labelled timber (because the demand function is assumed to be downward sloping). As usual, these (net) marginal benefits of current deforestation should equal its marginal costs in terms of future benefits forgone (λ). Equation (6.30) is nothing but an extension of the intertemporal non-arbitrage condition as stated by Hotelling (1931). In order to be indifferent between deforesting a unit of land now or in the future, the shadow price of the forest stock should increase at rate *r*, reduced with the net marginal value of forest conservation as perceived by the decision maker. This net marginal value equals the marginal benefits of forest conservation minus its marginal costs. The marginal returns on forested land are equal to the revenues that can be earned by logging a unit of forest land sustainably ($\gamma_S P_S$) and the forests' contribution to average soil productivity ($\beta\bar{P}_A(F_0\text{-}F)$). The opportunity costs of keeping the marginal unit of land forested are the revenues earned by having an extra unit of land under cultivation ($\bar{P}_A Z$) and the increase in revenues of sustainably produced timber (because of the increase in its price resulting from the decrease in supply; $\theta_S\gamma_S^{\,2}F$).

6.4.2.2 The long-run equilibrium size of the forest

On the basis of the equation of motion (6.23) and the first-order conditions (6.29) and (6.30), together with the inverse demand functions for timber (6.25) and (6.26), the model can be solved. The equilibrium size of the rainforest area can be found by setting the time derivatives ($\dot{F}$ and $\dot{\lambda}$) equal to zero. The resulting equilibrium forest size under a certification regime (F_C^*) is presented in equation (6.31)[17]:

[17]In the steady state, the transversality condition associated with this problem is met; see section 6.3.2.2.

$$F_C^* = F_0 - \left(\frac{\bar{P}_A \bar{Z} + r(1-\gamma_S)\bar{P}_U + \gamma_S^2 \theta_S F_0 - \gamma_S P_S(0)}{\bar{P}_A[2\beta - r\alpha] + 2\gamma_S^2 \theta_S} \right) \tag{6.31}$$

Analysing this equation, it becomes clear whether a certification regime will have a positive influence on the equilibrium size of the rainforest area. It is likely that the denominator of the second term on the RHS of (6.31) is positive: even if β is very low relative to α[18], the fact that the demand function for sustainably produced timber is downward sloping implies that the denominator is likely to be positive ($\theta_S > 0$).

The numerator of the second term on the RHS of (6.31) reflects the weighing of the benefits of deforesting the *first* unit of land and the benefits of managing it sustainably. This can be clarified by rewriting the numerator as follows:

$$(1-\gamma_S)\bar{P}_U + \frac{\bar{P}_A \bar{Z}}{r} + \frac{\theta_S \gamma_S^2 F_0}{r} \overset{?}{\geq} \frac{\gamma_S}{r} P_S(0) \tag{6.32}$$

As it is assumed that sustainable logging is more profitable for individual firms than unsustainable logging, the present value of sustainable logging ($\gamma_S P_S(0)/r$) exceeds initially the one-shot revenues of unsustainable logging, $(1-\gamma_S)\bar{P}_U$. However, the government also takes into account the present value of alternative uses of land ($\bar{P}_A \bar{Z}/r$) and the present value of the effect of deforesting the first unit of land on the price of sustainably produced timber ($\gamma_S^2 \theta_S F_0/r$). It is likely that the addition of these two terms results in a positive value of the numerator.

Thus, the equilibrium size of the rainforest area (F_C^*) is less than its initial size (F_0), even though switching to sustainable production techniques is profitable for all individual firms.

It is generally argued that a necessary condition for rainforest conservation is that the economic benefits of tropical rainforest conservation should be increased relative to the economic benefits of deforestation (see for

[18]That is, if the negative effect of *cumulative* deforestation on average soil productivity is very small compared to the positive influence of *current* deforestation on average soil productivity.

example Barbier *et al.*, 1994; Burgess, 1992; Vincent, 1990b). Equation (6.31) suggests that this argument is indeed valid: a decrease of the vertical intercept of the inverse demand function for unsustainably produced tropical timber ($\bar{P}_U$) or an increase of the vertical price intercept of sustainably produced timber ($\bar{P}_S$) leads to a larger long-run forest area. Although the optimal forest size is difficult to compare with the optimal size in the case of unsegmented timber markets (see equation 6.19) because the elasticities are likely to differ, the comparative statics analysis suggests that market segmentation indeed results in improved long-run forest conservation.

Thus, if forestry firms find it profitable to switch to sustainable logging techniques, the long run forest size will improve after the introduction of a certification regime. Additionally, the *quality* of the remaining forest also improves as *sustainable* logging is less degrading in terms of forest quality than *selective* logging.

6.4.2.3 The optimal depletion path towards the long-run equilibrium size of the forest

Having determined that it is likely that at least some deforestation is still desirable from the point of view of the local government, the question is how the depletion path is affected by the introduction of a certification regime. The depletion path can be calculated by taking the time derivative of the costate variable λ (6.29), inserting the result together with the equation of motion (6.23) into (6.30) and solving the resulting second-order differential equation (Apostol, 1967, pp. 322-328)[19]:

$$F_C(t) = (F_0 - F_C^*)\ EXP\left[-\left(\sqrt{\frac{1}{4}r^2 + \frac{\bar{P}_A(2\beta - r\alpha) + 2\gamma_S^2\theta_S}{2(1-\gamma_S)^2\,\theta_U}} - \frac{1}{2}r\right)t\right] + F_C^* \tag{6.33}$$

Depending on the parameter values of the inverse demand functions under certification compared to those without, the rate of deforestation

[19]These calculations yield a linear second-order differential equation. By calculating the roots of the system's discriminant, a positive and a negative root are found. This means that the equilibrium is again a saddle point. Equation (6.33) gives the saddle point path towards the long-run equilibrium size of the forest (see also Blanchard and Fisher, 1993, pp. 77-78).

can increase or decrease. Although it does not play a role in determining the long-run equilibrium *size* of the rainforest area under a certification regime, the price elasticity of the demand function for unsustainably produced timber does affect the *rate* at which forests are depleted. Taking the first derivative of equation (6.33) with respect to θ_U, a positive relationship is found: the lower θ_U (that is, the *higher* the price elasticity of demand[20]), the lower the forest stock in each period ($F_C(t)$). The intuition behind this result is that if the elasticity is high, a sharp increase in the quantity of timber sold does not lead to a large fall in its price. In other words, the higher the demand elasticity, the lower the cost of increasing current supply of unsustainably produced timber (in terms of the decrease in the price at which the entire stock of this type of timber can be sold). Thus, if the price elasticity of demand for unsustainably produced timber turns out to be high enough after the introduction of a certification regime compared to the elasticity before the introduction of the certification regime (that is, if θ_U is small enough relative to θ_M), it becomes profitable for governments of tropical countries to increase the instantaneous rate of deforestation.

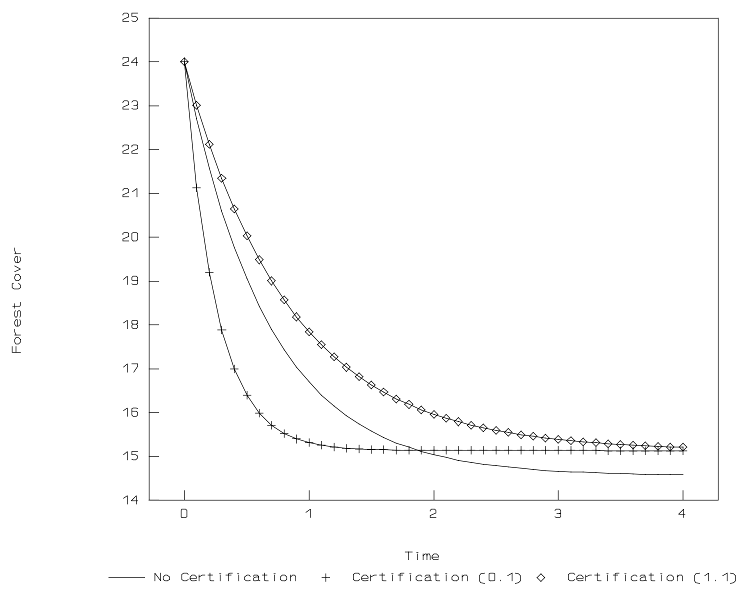
The obvious question is how this result compares with the depletion path without a certification regime. The depletion path that can be calculated by means of the model in 6.3.2.2 is the following:

$$F_M(t) = (F_0 - F_M^*) EXP\left[-\left(\sqrt{\frac{1}{4}r^2 + \frac{\bar{P}_A(2\beta - r\alpha) + 2\gamma_M\theta_M(\gamma_M - r(1-\gamma_M))}{2(1-\gamma_M)^2\theta_M}} - \frac{1}{2}r\right)t\right] + F_M^* \tag{6.34}$$

Just like in the case of the long-run equilibria, the depletion paths with and without certification are difficult to compare. However, the results can be shown graphically; see figure 6.1.

[20] The price elasticity of demand is $\frac{dy}{dP}\frac{P}{y}$ (see for example Varian, 1992, p. 253). Hence, in general, the lower θ, the higher the price elasticity of the demand function.

Figure 6.1: Comparison between the optimal depletion paths with and without certification for high and low elasticities of the demand function for unsustainably produced timber (θ_U=0.1 and θ_U=1.1 as compared to θ_M=1)



Parameter values: $\bar{P}_S$=60, θ_S=1.1, $\bar{P}_U$=35, $\bar{P}_M$=50, θ_M=1, $\bar{P}_A$=22.5, γ_S=0.4, γ_M=0.5, r=0.15, α=0.3, β=0.04, $\bar{Z}$=1, F_0=24.

In this figure three depletion paths are depicted. In addition to the depletion path in the absence of a certification regime (derived by inserting equation 6.19 into 6.34), two depletion paths have been drawn which can occur after the introduction of a certification regime. These paths differ as a result of differences in parameter θ_U. One path (marked with pluses) is drawn for a very high price elasticity of demand for unsustainably produced timber relative to the elasticity in absence of the regime (depicted as the straight line): θ_U is 0.1 while θ_M equals 1. The other path (characterised by diamonds) is drawn under the assumption that the unsustainable market turns out to be *less* elastic than with an unsegmented market: θ_U equals 1.1.

As is clear from this figure, if the price elasticity of the demand for conversion timber turns out to be lower than without a certification regime ($\theta_U > \theta_M$), a certification regime is unambiguously preferable from the point of view of the international community: in each period the size of the forest area is larger under a certification regime than without. However, if the elasticity of the demand for unsustainably produced timber is high enough ($\theta_U << \theta_M$), the long-run equilibrium forest area under a certification regime still exceeds the equilibrium forest size without such a regime, but in the short and medium run deforestation rates may be higher.

6.4.2.4 Analysis of the conditions under which the trade-off occurs and their likelihood

Thus, the adoption of a certification regime ensures that the size of the rainforest area is increased in the long run relative to the situation without segmentation, although it may cause the instantaneous rates of deforestation to increase in the short and medium term.[21] Of course, the actual occurrence of the depletion trade-off depends on the relative magnitudes of the price elasticities (θ_M, θ_S and θ_U) and on the size of the 'green premium' (*i.e.*, the difference between $\bar{P}_S$ and $\bar{P}_U$).

First, consider the influence of the relative magnitudes of the price elasticity of the demand function before certification and the price elasticities of demand for sustainably and unsustainably produced timber. Table 6.1 gives the number of periods after which the forest size under a certification scheme is larger than in the absence of certification, for different values of θ_S and θ_U. In other words, the number of periods is calculated at which the depletion path under a certification regime intersects the depletion path that occurs without such a regime, as depicted in figure 6.1.

[21]In terms of *quality* of the remaining forest in each period, the certification regime is beneficial since *sustainable* logging techniques rather than *selective* logging techniques are applied.

Table 6.1: Number of periods for which $F_C(t)$ is less than $F_M(t)$, for different combinations of the price elasticity of demand for sustainably produced and unsustainably produced timber (with θ_M = 1)

θ_U	θ_S=0.9	θ_S=1.0	θ_S=1.1
0.1	1.22	1.49	1.88
0.3	0.79	1.17	1.67
0.5	0	0.1	0.89
0.7	0	0	0

Parameter values: $\bar{P}_S$=60, $\bar{P}_U$=35, $\bar{P}_M$=50, θ_M=1, $\bar{P}_A$=22.5, γ_S=0.4, γ_M=0.5, r=0.15, α=0.3, β=0.04, $\bar{Z}$=1, F_0=24.

As is clear from table 6.1, an adverse short-term result will only occur if the demand function for unsustainably produced timber turns out to be more elastic than the demand function in the absence of a certification regime. The higher the elasticity of demand for nonlabelled timber (*i.e.* the lower θ_U), the larger the benefits of current deforestation, because an increase in deforestation D leads only to a small fall in P_U. However, the price elasticity of the demand function for sustainably produced timber also plays a role: the more inelastic the demand function for sustainably produced timber (*i.e.* the higher θ_S), the more the benefits of current deforestation increase because the resulting decrease in supply of sustainably produced timber leads to a sharp increase in P_S. Therefore, the more *inelastic* the demand function for *sustainably* produced timber and the more *elastic* the demand function for *unsustainably* produced timber, the more likely it is that the depletion trade-off will occur.

The second important precondition for the occurrence of the depletion trade-off is that the green premium should not be too high. Basically, two premia can be discerned (see also Varangis *et al.*, 1995). First, there is the difference between the maximum price of sustainably and of unsustainably produced timber ($\bar{P}_S$-$\bar{P}_U$). Second, there is the difference between the maximum price of sustainably produced timber and the maximum price at which timber was sold before the adoption of certification ($\bar{P}_S$-$\bar{P}_M$). Table 6.2 gives the number of periods for which short-term deforestation is higher under certification than without certification for different values of the vertical intercepts of the inverse demand functions while the location of the original inverse demand function P_M is fixed (at $\bar{P}_M = 50$).

Table 6.2: Number of periods for which $F_C(t)$ is less than $F_M(t)$ for different combinations of $\bar{P}_S$ and $\bar{P}_U$ (with $\bar{P}_M$=50)

$\bar{P}_U$	$\bar{P}_S$=60	$\bar{P}_S$=65	$\bar{P}_S$=70
40	2.65	1.02	0.50
35	1.88	0.88	0.41
30	1.52	0.76	0.31

Parameter values: θ_S=1.1, θ_U=0.1, θ_M=1, $\bar{P}_A$=22.5, γ_S=0.4, γ_M=0.5, r=0.15, α=0.3, β=0.04, $\bar{Z}$=1, F_0=24.

The results show that for both definitions of the green premium, an increase in the premium will reduce the likelihood of a trade-off. The reason is that an increase in both price gaps increases the optimal long-run size of the rainforest area by raising the benefits of forest conservation relative to deforestation. The larger this increase is, the smaller desired *cumulative* deforestation becomes; this implies that the resulting *rate* of deforestation in each period will necessarily be smaller. Summarising, the higher the price of sustainably produced timber relative to the price before certification and also the higher the price of sustainably produced timber relative to the price of unsustainably produced timber, the shorter the period in which short-run deforestation rates will be higher with certification than without.

Thus, it can be concluded that if the green premium is relatively small and if the elasticity of the demand function for uncertified timber is large enough, a trade-off can occur between long-run and short-run forest conservation. The question is how likely this situation is after the introduction of a certification regime. The main stimulus for sustainability created by the introduction of a certification regime is the positive price gap between sustainably and unsustainably produced timber. The extent of this gap will be limited by the possibilities of substitution (Varangis *et al.*, 1995, Annex 1). If for a particular type of use there are many alternatives for tropical timber (such as temperate timber, plastics or aluminium), a substantial price increase is not likely to occur after the introduction of a certification regime because demand will shift to alternative materials; unsustainably produced tropical timber will generally be sold in markets with a high elasticity of demand. A survey by Barbier *et al.* (1994, pp. 52-53) confirms this hypothesis: manufacturers believe that there is scope for a price premium only in the high quality product markets (such as the markets for quality joinery and furniture), whereas in markets with many close substitutes for tropical timber (such as the construction industry where temperate timber and non-wood products can be used) they do not see much room for a premium.

There is also some evidence on the size of the price gap resulting from the introduction of a certification regime. Surveys of research presented by Barbier *et al.* (1994, pp. 55-56) and Varangis *et al.* (1995) indicate that there is no unambiguous evidence that the price gap between the price of sustainably produced timber and the price of timber before the adoption of a certification regime will be sizeable. Several surveys indicate that consumers will only be prepared to pay a moderate premium for sustainably produced timber: in most cases this premium is less than 10 per cent while the majority of the respondents would be prepared to pay a premium between 1 and 5 per cent (FOE, 1992; Mattoo and Singh, 1994; Milland Fine Timber Ltd., 1990; MORI and WWF, 1991; Rice *et al.*, 1997; Varangis *et al.*, 1995; Winterhatter and Cassens, 1993; see also ESE, 1992 and Haji Gazali and Simula, 1994). However, there is some evidence that consumers in Western countries may be willing to abstain from purchasing non-certified timber, thus leading to an increase in the difference between the price of sustainably and unsustainably produced timber (Barbier *et al.*, 1994, p. 52).

6.4.3 Conclusions and policy recommendations

This section has presented an analysis of the consequences of the introduction of a certification regime for the long-term size of the rainforest area and for the depletion path. The main result is that, if the certification regime is successful in the sense that all logging firms switch to sustainable production techniques, long-run forest conservation will be improved (not only in terms of quality, but also in terms of quantity), but that the depletion path along which this higher equilibrium forest size is reached can become steeper, leading to faster deforestation in the short run. This depletion trade-off may occur if the price elasticity of demand for unsustainably produced timber turns out to be high compared to the price elasticity of the original demand function and relative to the price elasticity of demand for sustainably produced timber, *and* if the green premium turns out to be small.

Surveys among consumers and producers indicate that there is indeed reason for concern. Although the price of sustainably produced timber is likely to exceed the price of unsustainably produced timber, the possibility of an increase in short-run rates of deforestation cannot be excluded beforehand: the price elasticity of demand for unsustainably produced timber is likely to exceed the price elasticity of demand for certified timber, and the gap between the price of certified timber and the original timber price is not likely to be substantial.

The policy implication is that apart from monitoring the activities of individual firms, the decisions of the government of a tropical forest country should also be included in the certification regime. For instance, the price received by individual logging firms for sustainable timber can be made dependent on the overall rate of deforestation in this country, thus inducing its government to decrease the rate at which forested land is allocated to alternative use.

Hence, the overall conclusion of this section is that under the assumption that sustainable logging proves to be more profitable than unsustainable logging, introducing a certification regime is advisable in the long run and also in the short run if appropriate incentives are given to the local governments not to speed up the deforestation process. However, beforehand it is not obvious that the assumption will be met in reality. Given the estimates of the size of the green premium presented above, it cannot be ruled out in advance that the market situation may be such that it is *not* be profitable to switch to sustainable logging for individual firms: sustainable logging techniques can be much more expensive than less careful harvesting (Myers, 1980, p. 40; Rice *et al.*, 1997; Varangis *et al.*, 1995). If timber producers consider it not to be profitable to start sustainably managed timber production, they will opt out and concentrate on selling at noncertified markets only. The prices at these markets are likely to be lower than the prices at the unsegmented markets before the introduction of the certification regime. This implies that the indiscriminative demand-reducing trade measure models presented in section 6.3 again apply: the final impact of a certification regime may well be that the countries supplying the non-certified timber markets will increase their supply in order to at least keep up with the traditional level of foreign exchange received by selling their timber abroad, or that there is an additional incentive to allocate more forested land to alternative use.

6.5 Conclusions

This chapter has analysed the effectiveness of trade policy as an instrument to combat tropical deforestation. Two major types of trade policy measures have been addressed: policies that aim to affect the *level* of forestry activities and trade policy measures that aim to affect the *way* in which forests are exploited. The first type of measures are demand-reducing trade measures like tropical timber import bans and tariffs. The second type of measures distinguishes between sustainably and unsustainably produced timber: consumption of unsustainable produced timber is discouraged by selective import bans or tariffs, whereas consumption of sustainably produced timber may be encouraged through subsidisation.

The results of the land use models developed in this chapter indicate that trade policies should be implemented carefully: the desired effects are not always achieved. Demand-reducing policy measures aim to reduce the profitability of forestry activities so that their level will be reduced. These measures are only effective if there are no alternative types of land use for the forest regions, and if there are no short-run considerations that necessitate forest exploitation. If rainforest areas can be allocated to alternative types of land use (such as agriculture), depressing the profitability of forestry activities decreases the benefits of forest exploitation compared to the benefits of conversion to alternative land uses. Short-run considerations can also result in adverse results. For example, if a country is faced with a foreign exchange constraint and if it is highly dependent on import goods, a reduction in the profitability of forestry activities will result in increased harvesting in order to maintain the level of consumption of imported goods.

Also discriminative trade measures should be introduced carefully. In principle, these measures aim to increase the profitability of sustainable forestry relative to unsustainable exploitation, thus increasing the benefits of forest conservation: by making *sustainably* produced timber discernable from *unsustainably* produced timber through certification, the price of the former can be increased while the price of the latter can be depressed. However, although in the long run forest conservation will be improved, the resulting market segmentation may give incentives to increase the current rate of deforestation. The reason for this is that price increases are only viable in markets where the price elasticity of demand for timber products is limited. This implies that *certified* timber is likely to be sold at the high-quality markets, while *unsustainably* produced timber will be sold at markets with little room for price increases mainly because of easy substitution towards alternative materials (such as temperate timber and plastics). The combination of fairly inelastic demand for sustainably produced timber and a considerably higher elasticity of demand for unsustainably produced timber gives incentives to increase the current rate of deforestation. The underlying mechanism is that the high price elasticity of the latter type implies that its current supply can be increased without important negative effects on the price at which it is sold, while the resulting reduction in the supply of sustainably produced timber will cause a substantial price increase in the certified timber markets.

The general conclusion of this chapter is that trade measures may be used to stimulate forest conservation, but that positive results cannot be guaranteed: adverse results may be obtained in the short and long run if insufficient attention is paid to the resulting market situation and the decision-making processes of the actors involved.

Appendix 6.1: Comparative statics analysis of the adapted Barbier and Rauscher model

The long-run equilibrium system (consisting of equations 6.7 and 6.8) can be represented as follows (suppressing the asterisks that denote equilibrium):

$$\begin{bmatrix} -P^2(r-g_F)U_{cc} & PU_c g_{FF} + U_{FF} \\ -1 & g_F \end{bmatrix} \begin{bmatrix} dq \\ dF \end{bmatrix} = \begin{bmatrix} (r-g_F)[U_c + PqU_{cc}] \\ 0 \end{bmatrix} \left[dP \right] \tag{A6.1}$$

The required comparative statics result of demand-reducing policies can be found by applying Cramer's rule (Chiang, 1984, pp. 107-110). To do this, the sign of the determinant of the Hessian matrix (D) must be determined first:

$$D = -P^2(r-g_F)g_F U_{cc} + PU_c g_{FF} + U_{FF} \tag{A6.2}$$

The sign of this expression appears to be ambiguous. However, by analysing equation (6.7) it is clear that a necessary condition for an equilibrium to exist is that (r-g_F) must be positive given the fact that consumption and forest size both contribute positively to utility (U_c and U_F are both nonnegative). This means that the curve $\dot{q}$ = 0 is positively sloped in the (q,F) space:

$$\left.\frac{dq}{dF}\right|_{\dot{q}=0} = \frac{Pg_{FF}U_c + U_{FF}}{P^2(r-g_F)U_{cc}} > 0 \tag{A6.3}$$

Assuming an interior solution, the equilibrium is located at the point where the $\dot{q}$ = 0 curve cuts the $\dot{F}$ = 0 curve from below; see also Barbier and Rauscher (1994). In mathematical terms, the condition is:

$$\left.\frac{dq}{dF}\right|_{\dot{q}=0} > \left.\frac{dq}{dF}\right|_{\dot{F}=0} \tag{A6.4}$$

Calculating the slope of the $\dot{F}$ = 0 curve yields:

$$\left.\frac{dq}{dF}\right|_{\dot{F}=0} = g_F \tag{A6.5}$$

Combining (A6.4) and the results of (A6.3) and (A6.5) proves that D is negative.

Finally, it must be established whether the equilibrium is stable. Stability can be determined by analysing the dynamic system consisting of the differential equations of the state and control variables, $\dot{F}$ and $\dot{q}$ (Hanley *et al.*, 1997, pp. 193-196). Totally differentiating (6.2) and (6.5) with respect to time and inserting the resulting expressions into (6.6) yields (suppressing time notation):

$$\dot{q} = \frac{1}{P^2 U_{cc}} \left[(r - g_F) P U_c - U_F \right] \tag{A6.6}$$

The differential equation of the state variable is simply the equation of motion (6.3):

$$\dot{F} = g(F) - q \tag{A6.7}$$

Linearisation of both equations in the neighbourhood of the steady state gives the following system:

$$\begin{bmatrix} \dot{q} \\ \dot{F} \end{bmatrix} = \begin{bmatrix} (r - g_F) & -\dfrac{P U_c g_{FF} + U_{FF}}{P^2 U_{cc}} \\ -1 & g_F \end{bmatrix} \begin{bmatrix} q - q^* \\ F - F^* \end{bmatrix} \tag{A6.8}$$

The matrix containing the first derivatives in (A6.8) is referred to as the Jacobian matrix. Calculating the eigenvalues of this matrix, one positive and one negative eigenvalue are found. This implies that the equilibrium is a saddle point.